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REPORT ON
ANNUAL TESTING OF CONCRETE SPECIMENS AT TREAT ISLAND, MAINE

for

CANMET
ENERGY, MINES AND RESOURCES CANADA

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TABLE OF CONTENTS

	PAGE
TABLE OF CONTENTS	i
LIST OF TABLES	ii
1. INTRODUCTION	1
2. IDENTIFICATION AND PREPARATION OF TEST SPECIMENS	1
3. PULSE VELOCITY MEASUREMENTS	1
4. RESONANT FREQUENCY	2
5. PHOTOGRAPHIC AND COLOUR SLIDE RECORD	2
6. VISUAL EXAMINATION	2
7. NATURE AND DEGREE OF DETERIORATION	3
8. CONCLUSION	5
DIAGRAM OF WHARF	7
APPENDIX A	33

LIST OF TABLES

	PAGE
TABLE I - MIX PROPORTIONS	7
TABLE II - ULTRASONIC PULSE TRANSIT TIME READINGS	17
TABLE III - RESONANT FREQUENCY READINGS	22
TABLE IV - RATING OF SPECIMENS	27

1. INTRODUCTION

For 1987 The Department of Supply and Services awarded a contract to the University of New Brunswick covering the monitoring of 159 concrete test blocks incorporating fly ash/slag/silica fume that are located at Treat Island, Maine. A copy of the contract is given in Appendix A.

2. IDENTIFICATION AND PREPARATION OF TEST SPECIMENS

The concrete test specimens at Treat Island are listed in Table I and a diagram of specimen location is presented on page 6. The prisms were first cleaned of seaweed and silt with metal scrapers and wire brushes. They were then identified by the markings on the stainless steel straps which had been previously placed around them.

3. PULSE VELOCITY MEASUREMENTS

The nondestructive examination of concrete prisms utilized a battery powered "Pundit" manufactured by C.N.S. Electronics Ltd. (London, England) Serial No. 84111848. The meter was calibrated to a reference bar at 26.0 microseconds, at the beginning and periodically throughout the testing. Transducers of fifty millimeter diameter were used with a coupling medium made from kaolinite and glycerol. Readings were taken at the center of each specimen and are recorded in Table II.

4. RESONANT FREQUENCY

Transverse resonant frequency measurements were performed using procedures and with equipment meeting the requirements of ASTM Designation C215-60. The results are recorded in

Table III.

Prior to and after visiting the site, the operation of the equipment was verified using a 1' x 1' x 3' prism and a 3½" x 4" x 16" prism of concrete stored in the laboratory air. No change in reading was noted. Also the frequency readings of the oscillator was checked with the Department of Electrical Engineering standard and found to be in agreement with it. The mass of the driving unit had no noticeable effect on the frequency readings.

5. PHOTOGRAPHIC AND COLOUR SLIDE RECORD

Photographs of the individual specimens are in an enclosed envelope attached to this report. A set of slides has been stored in room B19, Head Hall, University of New Brunswick, Fredericton, for future reference. All slides and photographs were taken with a +1 setting on a Minolta XD11 camera.

6. VISUAL EXAMINATION

Using the rating system shown in Figure I the specimens were examined and the ratings and remarks recorded in Table IV. The evaluation was done independently by four people and in the few instances where differences of opinion

existed, a consensus was arrived at. A visual rating of two or greater was assumed to signify significant deterioration.

7. NATURE AND DEGREE OF DETERIORATION

For all air entrained concrete prisms the resonant frequency and ultrasonic pulse transit times indicate that the interior of the concrete is either not changing or is experiencing a very minor increase in stiffness with time. In some instances high transit times were noted and they are usually a consequence of problems of scaling on the surface of the specimens rather than any inherent reduction in strength of the concrete in the mass of the specimen. All evidence points to a surface type of deterioration and this can best be noted in the photographs and in the visual ratings. Based on nine years exposure, surface deterioration is clearly evident with a water to cement ratio of 0.6 and a cement replacement with slag of 45% or greater. With a water to cement ratio of 0.5, the replacement of 65% slag produces a noticeable deterioration as well. No difference in the performance of Type 10, 20 and Type 50 cement can be detected at this stage based on all specimens at the site.

After eight years exposure to sea water the specimens with a water to cement ratio of 0.6 and a replacement of cement in excess of 25% by both fly ash and slag produce significant deterioration. At a water to cement ratio of 0.4 and 0.5 the replacement of 60% of the

cement causes even greater deterioration. Again all evidence points to a surface type of deterioration as the ultrasonic pulse transit times and resonant frequency readings indicate no interior deterioration. Readings of transit time are variable from year to year and sometimes improve when a weak surface layer has come off.

After seven years exposure the lightweight concrete specimens with a cement content of 237 kg/m^3 (the lowest of all concrete placed by CANMET in this program) show significant deterioration for all types of cement and all levels of cement replacements.

Specimens containing lightweight aggregate show a pattern of deterioration that is different from normal weight concrete. With normal weight concrete there appears to be a potential for the mortar over the aggregate to come off in a sporadic fashion indicating a plane of weakness at the aggregate-cement paste interface. With lightweight concrete this is not noted and deterioration occurs by a uniform loss of the surface layer. The lightweight concrete specimen, HO3 has experienced top edge damage on the sea side as a result of a Corps of Engineer Lock Wall Specimen falling over on it.

Extensive deterioration of the non air-entrained specimens (SP3, SP4, and SP6) has taken place. There is nothing remaining of SP6 after five years. The results indicate that the addition of a superplasticizer tends to reduce the durability of a non air-entrained concrete.

There is the suggestion that the opposite might be true for air entrained concrete with the superplasticizer tending to make the air entrained concrete slightly more durable.The air-entrained specimens containing superplasticizers remain in good condition.

A general trend towards increasing surface deterioration can be noted in all specimens with a high water to cement ratio and a high percentage replacement of cement with slag. Specimens which contain both slag and fly ash show more surface deterioration than those which contain only slag for a given cement replacement value. However, specimens containing 80% slag do not show significant deterioration after four years exposure. Specimens containing silica fines have begun to show surface deterioration after four years exposure.

8. CONCLUSION

The replacement of up to 65% cement by slag has no apparent effect on the durability of concrete with a water to cement ratio of 0.4. A loss in durability is noted with a water to cement ratio of 0.5 with 65% replacement. With a water to cement ratio of 0.6 a significant increase in deterioration takes places at a 65% replacement level. In this latter case the deterioration is much more than just a surface phenomena and involves loss of aggregate particles.

Replacement of cement with both slag and fly ash produces severe deterioration when used at a 60% slag and

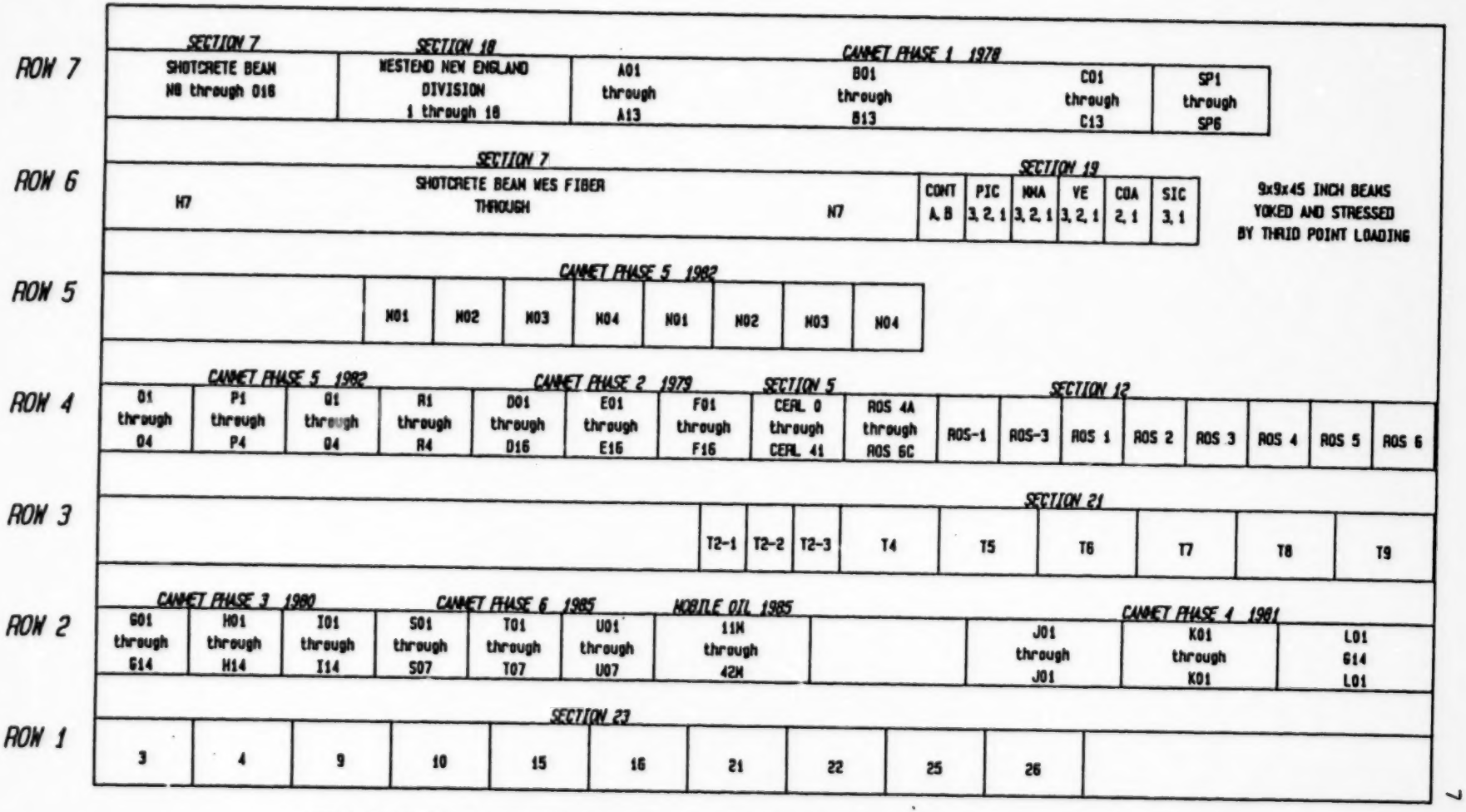
20% fly ash replacement rate even with water to cement ratios of 0.4.

It would appear that in many cases deterioration is on the threshold of proceeding rapidly and to obtain maximum information the specimens should be examined and studied closely over the next decade. During that time the effect of mix proportion, cement type and the role of supplementary cementing materials should become apparent.

← TO EASTPORT

NORTH ↑ TO BEACH

TO LUBEC →



ARRANGEMENT OF TEST SPECIMENS ON RACK AT SEVERE WEATHERING EXPOSURE STATION, TREAT ISLAND, MAINE, JULY 1986

TABLE I - Mix proportions - Phase I

Mix	Cement Type and Batch no.		W : (C+R) Ratio	Batch Quantities (kg/m³) Water	Cement	Slag	Fly Ash	Silica Fume	F.A.	C.A.	A.E.A (ml/m³)	Super Plasticizer (ml/m³)
A	Type 10	1	0.4	158	396	0	0	0	590	1196	360	0
		2		160	292	97	0	0	576	1176	580	0
		3		178	318	97	0	0	553	1138	480	0
		4		181	319	106	0	0	546	1132	440	0
		5		176	443	0	0	0	558	1146	430	0
		6		176	243	199	0	0	556	1141	870	0
		7		175	243	199	0	0	554	1138	860	0
		8		176	243	199	0	0	556	1140	870	0
		9		177	445	0	0	0	558	1147	370	0
		10		176	154	287	0	0	553	1137	1130	0
		11		179	155	290	0	0	536	1102	1120	0
		12		180	156	286	0	0	538	1106	1120	0
	Type 50	13		157	392	0	0	0	600	1196	490	0
		14		158	395	0	0	0	604	1203	500	0
	Type 10	15		179	446	0	0	0	560	1152	390	0
B	Type 10	1	0.5	161	329	0	0	0	641	1168	280	0
		2		161	244	82	0	0	638	1162	380	0
		3		161	247	82	0	0	644	1173	340	0
		4		151	231	77	0	0	651	1210	320	0
		5		161	320	0	0	0	668	1224	260	0
		6		166	183	150	0	0	629	1179	450	0
		7		166	183	150	0	0	629	1178	450	0
		8		167	183	150	0	0	630	1179	460	0
		9		167	335	0	0	0	656	1184	350	0
		10		166	116	215	0	0	634	1173	590	0
		11		167	117	217	0	0	640	1165	540	0
		12		168	118	219	0	0	645	1192	540	0
	Type 50	13		157	314	0	0	0	659	1203	350	0
		14		157	313	0	0	0	656	1198	350	0
	Type 10	15		166	331	0	0	0	648	1171	370	0

TABLE I (Cont'd) - Mix proportions - Phase I

Mix	Cement Type and Batch no.		W : (C+R) Ratio	Batch Quantities (kg/m³) Water	Cement	Slag	Fly Ash	Silica Fume	F.A.	C.A.	A.E.A (ml/m³)	Super Plasticizer (ml/m³)
C	Type 10	1	0.6	170	282	0	0	0	688	1222	270	0
		2		167	209	70	0	0	674	1209	320	0
		3		168	209	70	0	0	676	1210	300	0
		4		159	199	66	0	0	643	1290	300	0
		5		160	276	0	0	0	650	1248	260	0
		6		160	147	120	0	0	650	1249	390	0
		7		158	145	119	0	0	641	1231	440	0
		8		158	145	119	0	0	642	1232	410	0
		9		160	266	0	0	0	647	1243	260	0
		10		160	94	174	0	0	638	1250	380	0
		11		160	93	173	0	0	636	1246	380	0
		12		161	94	175	0	0	643	1260	390	0
	Type 50	13		163	272	0	0	0	656	1270	260	0
		14		163	272	0	0	0	663	1274	260	0
	Type 10	15		161	268	0	0	0	652	1253	260	0
SP	Type 10	1	0.5	167	334	0	0	0	654	1182	280	0
		2		166	332	0	0	0	649	1172	280	4720
		3		174	348	0	0	0	682	1232	0	6578
		4		174	349	0	0	0	683	1233	0	0
		5		165	335	0	0	0	647	1169	280	9730*
		6		172	345	0	0	0	675	1219	0	16554*

* Melamine-based superplasticizer was used

TABLE I (Cont'd) - Mix proportions - Phase II

Mix	Cement Type and Batch no.		W : (C+R) Ratio	Batch Quantities (kg/m³) Water	Cement	Slag	Fly Ash	Silica Fume	F.A.	C.A.	A.E.A (ml/m³)	Super Plasticizer (ml/m³)
D	Type 10	1	0.4	158	395	0	0	0	611	1256	390	0
		2		150	281	0	94	0	580	1192	960	0
		3		150	281	0	94	0	580	1192	960	0
		4		149	297	0	93	0	576	1184	950	0
		5		164	411	0	0	0	586	1198	370	0
		6		160	161	161	80	0	563	1152	1290	0
		7		160	161	161	80	0	564	1152	1290	0
		8		161	162	162	81	0	568	1162	1460	0
		9		164	411	0	0	0	582	1198	420	0
		10		165	83	247	82	0	564	1161	2130	0
		11		168	84	252	84	0	554	1138	1910	0
		12		168	84	252	84	0	554	1140	2070	0
	Type 50	13		153	384	0	0	0	551	1245	310	0
		14		151	379	0	0	0	542	1288	280	0
	Type 10	15		165	412	0	0	0	586	1191	300	0
	Type 20	16		148	370	0	0	0	530	1319	270	0
		17		141	355	0	0	0	510	1385	260	0
E	Type 10	1	0.5	160	320	0	0	0	664	1208	160	0
		2		160	240	0	80	0	662	1211	590	0
		3		154	231	0	77	0	637	1213	640	0
		4		151	227	0	76	0	628	1255	570	0
		5		149	298	0	0	0	657	1260	150	0
		6		160	128	128	64	0	686	1163	640	0
		7		152	122	122	61	0	652	1185	610	0
		8		154	123	123	62	0	662	1202	580	0
		9		148	297	0	0	0	656	1257	180	0
		10		143	57	171	58	0	611	1246	770	0
		11		147	59	176	59	0	628	1241	680	0
		12		148	59	177	59	0	631	1247	680	0
	Type 50	13		152	304	0	0	0	657	1258	290	0
		14		138	275	0	0	0	666	1274	240	0
	Type 10	15		147	293	0	0	0	646	1208	190	0
	Type 20	16		149	297	0	0	0	629	1233	320	0
		17		133	264	0	0	0	695	1245	260	0

TABLE I (Cont'd) - Mix proportions - Phase II

Mix	Cement Type and Batch no.		W : (C+R) Ratio	Batch Quantities (kg/m³) Water	Cement	Slag	Fly Ash	Silica Fume	F.A.	C.A.	A.E.A (ml/m³)	Super Plasticizer (ml/m³)
F	Type 10	1	0.6	148	246	0	0	0	724	1247	140	0
		2		145	182	0	61	0	713	1229	440	0
		3		139	174	0	58	0	743	1179	490	0
		4		141	175	0	59	0	748	1187	460	0
		5		139	233	0	0	0	744	1179	210	0
		6		146	97	97	49	0	745	1166	540	0
		7		145	98	98	49	0	666	1239	490	0
		8		142	96	96	48	0	727	1215	480	0
		9		137	226	0	0	0	767	1147	190	0
		10		138	46	137	46	0	775	1160	540	0
		11		136	46	136	45	0	770	1152	500	0
		12		140	46	139	46	0	759	1181	510	0
	Type 50	13		135	225	0	0	0	745	1230	170	0
		14		135	224	0	0	0	743	1228	170	0
	Type 10	15		143	237	0	0	0	758	1202	150	0
	Type 20	16		126	209	0	0	0	729	1203	200	0
		17		129	216	0	0	0	721	1242	170	0

TABLE I (Cont'd) - Mix proportions - Phase III

Mix	Cement Type and Batch no.		Nominal Cement (kg/m³)	Batch Quantities (kg/m³) Water	Cement	Slag	Fly Ash	Silica Fume	F.A.	C.A.	A.E.A (ml/m³)	Super Plasticizer (ml/m³)
G	Type 10	1	237	212	240	0	0	0	866	583	70	0
		2		217	241	0	0	0	873	586	71	0
		3		215	183	61	0	0	869	589	78	0
		4		219	184	62	0	0	870	589	75	0
		5		214	183	61	0	0	865	586	78	0
		6		210	241	0	0	0	871	585	71	0
		7		210	135	111	0	0	877	596	92	0
		8		207	133	109	0	0	864	587	94	0
		9		210	133	109	0	0	862	585	94	0
		10		204	239	0	0	0	864	581	78	0
		11		207	84	157	0	0	856	583	99	0
		12		209	85	158	0	0	868	592	94	0
		13		206	85	158	0	0	863	588	99	0
	Type 50	14		202	241	0	0	0	871	586	125	0
		15		196	243	0	0	0	879	591	135	0
H	Type 10	1	356	215	356	0	0	0	777	589	102	0
		2		216	355	0	0	0	775	589	111	0
		3		222	268	90	0	0	764	590	121	0
		4		226	263	88	0	0	751	580	119	0
		5		220	266	88	0	0	758	584	120	0
		6		221	353	0	0	0	771	585	113	0
		7		220	198	162	0	0	750	587	155	0
		8		221	199	163	0	0	753	589	140	0
		9		220	199	163	0	0	754	590	133	0
		10		217	355	0	0	0	774	588	113	0
		11		209	129	239	0	0	747	592	191	0
		12		215	128	238	0	0	761	598	167	0
		13		226	122	227	0	0	768	594	159	0
	Type 50	14		200	352	0	0	0	759	595	194	0
		15		202	355	0	0	0	765	600	167	0

TABLE I (Cont'd) - Mix proportions - Phase III

Mix	Cement Type and Batch no.		Nominal Cement (kg/m³)	Batch Quantities (kg/m³) Water	Cement	Slag	Fly Ash	Silica Fume	F.A.	C.A.	A.E.A (ml/m³)	Super Plasticizer (ml/m³)
I	Type 10	1	475	222	473	0	0	0	661	571	151	0
		2		227	475	0	0	0	664	573	154	0
		3		224	360	129	0	0	653	574	195	0
		4		225	363	121	0	0	659	578	178	0
		5		225	357	119	0	0	667	580	187	0
		6		247	474	0	0	0	646	568	198	0
		7		247	261	214	0	0	616	565	231	0
		8		243	261	214	0	0	616	565	252	0
		9		239	271	221	0	0	638	575	279	0
		10		221	469	0	0	0	655	567	173	0
		11		214	166	307	0	0	628	565	266	0
		12		220	169	314	0	0	641	577	272	0
		13		217	167	310	0	0	635	571	269	0
	Type 50	14		211	465	0	0	0	648	576	351	0
		15		212	465	0	0	0	650	577	352	0

TABLE I (Cont'd) - Mix proportions - Phase IV

Mix	Cement Type and Batch no.		W : (C+R) Ratio	Batch Quantities (kg/m³) Water	Cement	Slag	Fly Ash	Silica Fume	F.A.	C.A.	A.E.A (ml/m³)	Super Plasticizer (ml/m³)
J	Type 10	1	0.4	178	440	0	0	0	586	1128	415	0
		2		178	440	0	0	0	586	1128	376	0
		3		179	442	0	0	0	589	1134	345	0
		4		170	318	0	106	0	529	1140	832	0
		5		163	305	0	101	0	507	1239	683	0
		6		170	319	0	106	0	530	1239	633	0
	Type 50	7		171	429	0	0	0	605	1214	367	0
		8		166	414	0	0	0	627	1171	427	0
K	Type 10	1	0.5	174	348	0	0	0	639	1211	306	0
		2		173	346	0	0	0	635	1204	333	0
		3		173	345	0	0	0	634	1201	325	0
		4		163	244	0	81	0	625	1249	519	0
		5		160	240	0	80	0	632	1244	590	0
		6		160	241	0	80	0	622	1236	580	0
	Type 50	7		156	311	0	0	0	688	1226	337	0
		8		150	300	0	0	0	695	1246	324	0
L	Type 10	1	0.6	159	263	0	0	0	730	1217	229	0
		2		160	260	0	0	0	737	1201	226	0
		3		158	262	0	0	0	731	1210	228	0
		4		148	183	0	61	0	742	1225	425	0
		5		149	184	0	61	0	760	1226	426	0
		6		148	186	0	62	0	751	1239	430	0
	Type 50	7		147	244	0	0	0	777	1241	255	0
		8		146	242	0	0	0	769	1229	286	0

TABLE I (Cont'd) - Mix proportions - Phase IV

Mix	Cement Type and Batch no.		W : (C+R) Ratio	Batch Quantities (kg/m³) Water	Cement	Slag	Fly Ash	Silica Fume	F.A.	C.A.	A.E.A (ml/m³)	Super Plasticizer (ml/m³)
M	Type 10	1	0.4	174	435	0	0	0	581	1120	435	0
		2		177	443	0	0	0	590	1137	407	0
		3		179	89	357	0	0	571	1146	1193	849
		4		177	88	354	0	0	567	1137	1906	1183
N	Type 10	1	0.5	164	329	0	0	0	729	1147	143	0
		2		163	327	0	0	0	726	1143	177	0
		3		162	65	259	0	0	710	1130	456	333
		4		160	64	256	0	0	701	1115	389	343
O	Type 10	1	0.6	154	260	0	0	0	751	1148	143	0
		2		155	257	0	0	0	754	1194	177	0
		3		151	260	202	0	0	724	1159	456	0
		4		153	259	204	0	0	733	1174	389	0
P	Type 10	1	0.6	157	260	0	0	0	802	1101	203	0
		2		155	257	0	0	26	767	1087	368	957
		3		158	262	0	0	39	764	1105	468	2248
		4		157	259	0	0	52	742	1095	776	2894
Q	Type 10	1	0.6	146	243	0	0	0	804	1125	196	0
		2		146	218	0	0	24	799	1125	417	1572
		3		146	206	0	0	36	790	1125	540	2525
		4		147	196	0	0	49	791	1135	672	2674
R	Type 10	1	0.6	167	278	0	0	0	838	1129	0	0
		2		171	256	0	0	28	848	1159	0	3250
		3		170	240	0	0	43	837	1149	0	4236
		4		170	226	0	0	56	834	1149	0	4409

TABLE I (Cont'd) - Mix proportions - Phase VI

Mix	Cement Type and Batch no.		W : (C+R) Ratio	Batch Quantities (kg/m³) Water	Cement	Slag	Fly Ash	Silica Fume	F.A.	C.A.	A.E.A (ml/m³)	Super Plasticizer (ml/m³)
S	Type 10	1	632	238	492	-	84	39	527	561	2410	5360
		2		243	502	-	85	40	493	573	1684	2882
		5		244	632	-	-	-	508	577	652	2740
		6		253	501	50.2	85	40	403	584	958	5196
		7		252	505	50.6	86	40	407	589	912	5990
T	Type 10	1	509	227	408	-	70	33	587	606	594	2716
		2		228	408	-	69	32	582	601	657	2712
		5		230	509	-	-	-	612	600	361	2462
		6		245	391	48.8	66	31	570	598	518	3710
		7		237	394	48.2	67	32	563	590	630	4770
U	Type 10	1	375	225	303	-	51	24	692	596	448	3792
		2		236	308	-	52	25	704	616	232	2533
		5		235	375	-	-	-	799	590	210	2146
		6		228	307	51.2	52	25	658	591	297	3165
		7		221	303	50.7	52	24	668	600	292	3736

TABLE I (Cont'd) - Mix proportions - Phase VII

Mix	Cement Type and Batch no.	Nominal Cement (kg/m³)	Batch Quantities (kg/m³) Water	Cement	Fiber	Fly Ash	Silica Fume	F.A.	C.A.	A.E.A (ml/m³)	Super Plasticizer (ml/m³)
500	Type 10 1	500	140	500	-	-	30	700	550	800	4000
500	2		140	500	-	-	30	700	550	800	4000
500	3		140	500	-	-	30	700	550	800	4000
400	1	400	145	400	-	-	30	660	635	750	2500
400	2		145	400	-	-	30	660	635	750	2500
400	3		145	400	-	-	30	660	635	750	2500

TABLE II

Ultrasonic Pulse Transit Time Readings (microseconds)

PRISM NO.	READING
A01	203.3
A02	213.8
A03	213.3
A05	209.2
A06	216.4
A07	217.0
A09	207.0
A10	219.8
A11	222.3
A13	208.8
B01	210.8
B02	210.7
B03	210.7
B05	211.3
B06	213.6
B07	213.3
B09	211.3
B10	216.4
B11	217.4
B13	206.4
C01	213.0
C02	210.0
C03	212.0
C05	211.4
C06	212.0
C07	212.6
C09	209.3
C10	214.1
C11	215.3
C13	206.8
SP1	208.3
SP2	211.3
SP3	-
SP4	-
SP5	206.3
SP6	-

TABLE II (cont'd)

Ultrasonic Pulse Transit Time Readings (microseconds)

PRISM NO.	READING
D01	203.6
D02	210.0
D03	208.8
D05	204.7
D06	220.7
D07	222.1
D09	204.4
D10	232.1
D11	234.8
D13	210.2
D16	205.2
E01	207.8
E02	211.4
E03	215.5
E05	209.8
E06	221.3
E07	217.0
E09	209.1
E10	231.6
E11	225.6
E13	205.6
E16	208.4
F01	211.5
F02	213.0
F03	215.8
F05	214.4
F06	224.3
F07	221.3
F09	217.8
F10	250.2
F11	274.4
F13	212.4
F16	218.7

TABLE II (cont'd)

Ultrasonic Pulse Transit Time Readings (microseconds)

PRISM NO.	READING
G01	243.8
G02	237.3
G03	234.7
G06	236.0
G07	231.2
G08	235.7
G10	239.6
G11	239.8
G12	236.2
G14	244.7
H01	226.4
H03	222.3
H04	227.8
H06	225.8
H07	222.3
H08	222.4
H10	226.7
H11	222.7
H12	223.8
H14	226.8
I01	221.4
I03	218.5
I04	217.6
I06	222.4
I07	220.3
I08	222.1
I10	224.4
I11	223.7
I12	224.0
I14	220.7
J01	196.1
J02	193.0
J04	201.6
J05	198.6
J07	190.0

TABLE II (cont'd)
Ultrasonic Pulse Transit Time Readings (microseconds)

PRISM NO.	READING
K01	194.5
K02	198.2
K04	192.9
K05	198.0
K07	198.4
L01	200.7
L02	201.2
L04	200.4
L05	196.4
L07	204.2
M1	193.4
M2	193.3
M3	211.2
M4	210.4
N1	198.4
N2	192.7
N3	216.4
N4	218.4
O1	198.4
O2	200.1
O3	219.7
O4	215.6
P1	203.2
P2	203.7
P3	199.2
P4	205.7
Q1	204.2
Q2	202.4
Q3	201.7
Q4	209.6
R1	198.6
R2	190.1
R3	193.9
R4	197.7

TABLE II (cont'd)
Ultrasonic Pulse Transit Time Readings (microseconds)

PRISM NO.	1 TOP RIGHT	2 TOP LEFT	3 BOTTOM LEFT	4 BOTTOM RIGHT	5 CENTRE
S01	226.5	226.8	225.0	223.6	225.4
S02	223.4	224.1	221.8	222.4	224.1
S05	219.0	218.8	216.4	216.0	217.8
S06	225.1	225.7	224.6	224.7	226.4
S07	225.0	224.0	225.1	223.9	225.4
T01	224.7	224.8	223.2	223.4	223.6
T02	224.3	227.2	223.3	222.6	226.0
T05	221.2	221.7	218.8	218.7	219.7
T06	224.9	224.8	226.3	225.6	225.4
T07	227.3	226.5	231.0	229.9	227.7
U01	229.0	227.7	227.0	225.2	226.5
U02	226.0	225.4	224.4	225.1	226.6
U05	224.8	225.7	222.2	220.8	224.4
U06	231.0	230.7	226.2	229.4	228.8
U07	226.6	226.4	225.4	224.1	226.7
500-1	214.6	215.5	212.9	212.3	215.4
500-2	214.8	215.0	213.9	212.4	215.9
500-3	214.4	214.6	213.1	212.5	215.8
400-1	222.1	222.2	219.7	220.6	223.6
400-2	228.8	223.8	220.0	220.2	225.9
400-3	222.9	217.7	219.7	219.3	223.2

TABLE III

Resonant Frequency Readings

SERIES	1st HARMONIC FREQUENCY (H_Z)
A01	1207
A02	1158
A03	1146
A05	1184
A06	1177
A07	1147
A09	1183
A10	1157
A11	1162
A13	1205
B01	1145
B02	1161
B03	1165
B05	1168
B06	1155
B07	1176
B09	1155
B10	1142
B11	1111
B13	1175
C01	1154
C02	1162
C03	1171
C05	1134
C06	1172
C07	1144
C09	1137
C10	1170
C11	1160
C13	1183
SP1	1165
SP2	1138
SP3	Damaged
SP4	Damaged
SP5	1158
SP6	Missing

TABLE III (cont'd)

Resonant Frequency Readings

SERIES	1st HARMONIC FREQUENCY (H_Z)
D01	1187
D02	1131
D03	1167
D05	1220
D06	1157
D07	1168
D09	1177
D10	1081
D11	1084
D13	1158
D16	1193
E01	1185
E02	1172
E03	1129
E05	1152
E06	1122
E07	1141
E09	1180
E10	1072
E11	1082
E13	1187
E16	1144
F01	1144
F02	1145
F03	1120
F05	1153
F06	1085
F07	1088
F09	1095
F10	1044
F11	1046
F13	1139
F16	1089
G01	1005
G03	1012
G04	1015
G06	1018
G07	1072
G08	1072
G10	1008
G11	1065
G12	1053
G14	999

TABLE III (cont'd)

Resonant Frequency Readings

SERIES	1st HARMONIC FREQUENCY (H_z)
H01	1082
H03	1092
H04	1073
H06	1080
H07	1094
H08	1091
H10	1083
H11	1107
H12	1104
H14	1075
I01	1095
I03	1115
I04	1109
I06	1088
I07	1109
I08	1091
I10	1066
I11	1073
I12	1094
I14	1094
J01	1225
J02	1224
J04	1186
J05	1228
J07	1281
K01	1235
K02	1219
K04	1267
K05	1241
K07	1202
L01	1191
L02	1162
L04	1205
L05	1233
L07	1186
M01	1232
M02	1243
M03	1107
M04	1186

TABLE III (cont'd)

Resonant Frequency Readings

SERIES	1st HARMONIC FREQUENCY (H_z)
N01	1197
N02	1243
N03	1196
N04	1161
O01	1196
O02	1184
O03	1141
O04	1163
P01	1166
P02	1184
P03	1206
P04	1168
Q01	1167
Q02	1194
Q03	1193
Q04	1194
R01	1190
R02	1248
R03	1260
R04	1233
S01	1086
S02	1089
S05	1098
S06	1056
S07	1063
T01	1090
T02	1078
T05	1109
T06	1076
T07	1066
U01	1076
U02	1076
U05	1095
U06	1067
U07	1096

TABLE III (cont'd)

Resonant Frequency Readings

SERIES	1st HARMONIC FREQUENCY (H_Z)
400-1	1096
400-2	1084
400-3	1085
500-1	1113
500-2	1114
500-3	1122

TABLE IV

Rating of Specimens

SERIES	RATING	REMARKS
A01	0	
A02	1	
A03	1	
A05	1	
A06	1	Some loss of mortar
A07	1	Some loss of mortar
A09	1	
A10	1	Some loss of mortar
A11	1	Some loss of mortar
A13	1	Some loss of mortar
B01	0	
B02	2	Some loss of mortar
B03	1	Some loss of mortar
B05	1	
B06	2	Some loss of mortar
B07	2	Some loss of mortar
B09	1	
B10	3	Some loss of mortar
B11	3	Large spall-holds water, damage spreading to 80 x 120 ellipse
B13	1	Some loss of mortar

TABLE IV (cont'd)

Rating of Specimens

SERIES	RATING	REMARKS
C01	2	Slight end damage
C02	1	Slight end damage
C03	3	2 mm loss of mortar
C05	0	Slight end scaling
C06	2	Some end damage
C07	3	5 mm loss of mortar
C09	1	
C10	4	7 mm loss of mortar
C11	4	6 mm loss of mortar
C13	2	2 mm loss of water
SP1	2	Some loss of mortar
SP2	1	Some loss of mortar
SP3	8	30% of specimen remaining
SP4	7	90% of specimen remaining
SP5	2	Some loss of mortar
SP6	10	0% of specimen remaining
D01	1	Some loss of mortar
D02	1	Some loss of mortar
D03	1	1 mm loss of mortar
D05	1	1 mm loss of mortar
D06	2	1 mm loss of mortar
D07	3	2 mm loss of mortar
D09	1	1 mm loss of mortar
D10	4	5 mm loss of mortar
D11	4	4 mm loss of mortar
D13	0	Some loss of mortar
D16	1	Some loss of mortar
E01	1	Popout
E02	1	Some loss of mortar
E03	1	Some loss of mortar
E05	1	Some loss of mortar
E06	3	3 mm loss of mortar
E07	5	4 mm loss of mortar
E09	1	1 mm loss of mortar
E10	4	Aggregates exposed on sides
E11	4	Aggregates exposed on sides
E13	1	
E16	0	

TABLE IV (cont'd)

Rating of Specimens

SERIES	RATING	REMARKS
F01	1	Some loss of mortar
F02	2	1 mm loss of mortar
F03	2	2 mm loss of mortar
F05	1	1 mm loss of mortar
F06	5	Loss of aggregates
F07	5	Loss of aggregates
F09	2	Some loss of mortar
F10	6	Loss of aggregates
F11	5	Loss of aggregates
F13	1	Some loss of mortar
F16	1	Some loss of mortar
G01	2	Loss of 2 mm of mortar
G03	3	Loss of 3 mm of mortar
G04	3	Loss of 4 mm of mortar
G06	2	Loss of 2 mm of mortar
G07	3	Loss of 3 mm of mortar
G08	3	Loss of 4 mm of mortar
G10	3	Loss of 3 mm of mortar
G11	4	Loss of 4 mm of mortar
G12	4	Loss of 3 mm of mortar
G14	3	Loss of 2 mm of mortar
H01	0	Loss of 0 mm of mortar
H03	2	Loss of 2 mm of mortar
H04	2	Loss of 2 mm of mortar
H06	1	Loss of 1 mm of mortar
H07	1	Loss of 1 mm of mortar
H08	1	Loss of 2 mm of mortar
H10	1	Loss of 0 mm of mortar
H11	2	Loss of 1 mm os mortar
H12	2	Loss of 2 mm of mortar
H14	1	Loss of 1 mm of mortar
I01	1	Loss of 1 mm of mortar
I03	1	Spall - 35 mm ø
I04	1	Loss of 1 mm of mortar
I06	1	Loss of 1 mm of mortar
I07	1	Loss of 1 mm of mortar
I08	2	Loss of 1 mm of mortar
I10	1	Loss of 1 mm of mortar
I11	1	Loss of 2 mm of mortar
I12	2	Loss of 1 mm of mortar
I14	1	Some loss of mortar

TABLE IV (cont'd)

Rating of Specimens

SERIES	RATING	REMARKS
J01	1	
J02	1	
J04	0	Some loss of mortar
J05	2	
J07	1	
K01	1	
K02	1	
K04	2	Loss of 1 mm of mortar
K05	2	Loss of 1 mm of mortar
K07	1	Some loss of mortar
L01	1	
L02	1	Some loss of mortar
L04	3	Loss of 4 mm of mortar
L05	3	Loss of 3 mm of mortar
L07	1	10 aggregates exposed
M01	1	
M02	0	
M03	1	
M04	0	
N01	0	
N02	0	
N03	1	Some loss of mortar
N04	1	Some loss of mortar
O01	1	Some loss of mortar
O02	1	Some loss of mortar
O03	3	2 mm loss of mortar
O04	2	1 mm loss of mortar
P01	2	Some loss of mortar
P02	2	Some loss of mortar
P03	3	Some loss of mortar
P04	3	Some loss of mortar
Q01	2	1 mm loss of mortar
Q02	2	Some loss of mortar
Q03	3	1 mm loss of mortar
Q04	3	2 mm loss of mortar
R01	1	Some loss of mortar
R02	2	Some loss of mortar
R03	2	Some loss of mortar
R04	4	4 mm loss of mortar

All remaining specimens have a visual rating of 0 (zero).

TABLE IV (cont'd)

Rating of Specimens

SERIES	RATING	REMARKS
S01	0	
S02	0	
S05	0	
S06	0	
S07	0	
T01	0	
T02	0	
T05	0	
T06	0	
T07	0	
U01	0	
U02	1	
U05	0	
U06	0	
U07	0	
500-1	0	
500-2	0	
500-3	0	
400-1	0	
400-2	0	
400-3	0	

APPENDIX "A"

STATEMENT OF WORK

A. Yearly Inspection of Fly Ash/Slag/Silica Fume Concrete Test Specimens at Treat Island

The contractor shall travel to Treat Island and clean, test and inspect 159 fly ash/slag/silica fume concrete prisms (305x305x910 mm) that have been installed at Treat Island during the period 1978-1987.

The contractor shall carry out the following:

a) clean and label each concrete prism
b) visual inspection and rating of each concrete prism
c) provide one colour print of each specimen
d) provide one colour slide of each specimen
e) retag specimens where necessary
f) obtain available temperature records to determine the number of cycles of freezing and thawing for the 1986-1987 winter
g) provide 5 copies of the report on testing and inspection; the report shall also include a photographic record of the test specimens.

B. Installation of Temperature Sensors at Treat Island

The contractor shall obtain two TL-100 Submersible Temperature Loggers from the manufacturer, Richard Bracker Research Ltd. One of them shall be installed in air at mid-tide level and one shall be cast into a 305x305x910 mm concrete prism and placed similarly. Prior to installation in air or casting in concrete the performance and suitability of the temperature loggers will be verified by preprogramming with an IBM PC portable computer and testing. Performance test will include temperature cycling in air (-20 to +40°C) and water (-0 to 30°C). After 90 days of moist curing of the concrete prism (w/c = 0.4, 5-7% air, Blagdon FA and CA) the prism containing the temperature logger and the logger for monitoring air temperature will be transported to Eastport, Maine and installed at the Treat Island Exposure site on or before November 1, 1987. The temperature logger for monitoring air temperature shall be secured to the deck using a steel frame and lag bolts. The concrete temperature recorder will be placed in a compartment in the concrete prism so that it can be retrieved for servicing and returned to the prism.

The contractor shall provide 5 copies of the report describing the testing and installation of the above system.

C. Preparation of Display Panels for 1988 Inspection at Treat Island

The contractor shall prepare a series of COREX plastic panels (approximately 6 mm thick) to describe the progress of on-going test programs at Treat Island, stating the following:

1. Phase No.
2. Title
3. Purpose
4. Results
5. Conclusion

.../

Individual Panels shall be prepared for Phases I(a) and I(b) and Phase 2 to Phase 7 inclusive plus an additional two plastic panels that give details of the 1987 work. This gives a total of 10 panels that will have a width and length sufficient to hold the required text.

The lettering shall be by vinyl, stencil or computer graphics lettering. If computer graphics lettering is used it shall be on plastic based paper or plastic coated paper with waterproof ink that can be subsequently glued to the COREX panels. Also if computer graphics lettering is used the text shall be readily updated for subsequent biennial inspections.

Panels shall be prepared in 1987 and stored until August 1988 at which time it will be transported to the Treat Island exposure site and displayed at the time of biennial inspection.

Deadlines

Part A - Completion of Report:	October 31, 1987
Part B - Completion of Report:	November 30, 1987
part C - Completion of Displays:	January 31, 1988

CONTRACT REPORT NUMBER 79044-01-SS VOL.I
CONTRACTOR: University of New Brunswick
REQUISITION NUMBER 23440-7-9044

DEPARTMENT OF

CIVIL ENGINEERING

INSTALLATION OF AN AUTOMATED TEMPERATURE MONITORING SYSTEM AT TREAT ISLAND, MAINE

for

CANMET
ENERGY, MINES AND RESOURCES CANADA

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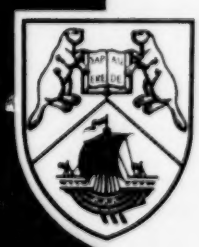

UNIVERSITY OF NEW BRUNSWICK

FREDERICTON NEW BRUNSWICK CANADA

DECEMBER 1987

Laboratory Report on the

INSTALLATION OF AN AUTOMATED TEMPERATURE MONITORING SYSTEM

AT THE SEVERE WEATHERING CONCRETE EXPOSURE SITE TREAT ISLAND, MAINE

for the

DEPARTMENT OF ENERGY, MINES AND RESOURCES

DSS File No. 20ST.23440-7-9044

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TABLE OF CONTENTS

	PAGE
1. INTRODUCTION	1
2. MATERIALS	2
3. PLACEMENT OF THE TEMPERATURE SENSORS	3
4. BATCHING & MIXING	4
5. TESTING OF THE CONCRETE	5
6. INSTALLATION OF TEMPERATURE RECORDER AT TREAT ISLAND	5
7. PERFORMANCE TESTS ON THE XL-800	6
APPENDIX A	7
APPENDIX B	12
APPENDIX C	15
TABLES	23

Laboratory Report

1. Introduction

CANMET has been involved in evaluating the long term marine durability of concrete at the U.S. Army Corps severe weathering exposure station at Treat Island, Maine since 1978. To date CANMET has placed a total of 165 prisms of nominal dimensions of 300mm x 300mm x 900mm at the site. This test group covers a broad spectrum of concretes incorporating various quantities of blast furnace slag, fly ash, and silica fume and a range of water cement ratios.

The two main driving forces responsible for deterioration of concrete prisms at the site are freezing-thawing and chemical interaction with seawater. Freeze-thaw deterioration is directly related to the total number of freeze-thaw cycles the specimen experiences. The pupose of this present work is to accurately determine the number of freeze thaw cycles the concrete undergoes at various levels of cover and to provide a low cost, long term solution to the temperature recording problems at Treat Island.

The U.S. Army Corps of Engineers has had temperature recording equipment installed at the Treat Island Site for well over a decade. Because of the remote nature of the site it was necessary at the time of installation of the equipment to use mechanical recorders with tube type temperature sensors. These recorders require weekly winding and chart changes. At one

time three sensors were used for collecting data, one in the center of a 2 foot cube, one in the center of 6in x 6in x 30in prism and one located in the air. Over the years vandalism and weathering has resulted in only one sensor (in the small prism) remaining operable and this only after extensive repairs.

It was felt that based on the poor performance of the mechanical equipment over the last few years that a renewing of the temperature sensing capability at the Treat Island Site with a more advance technolgy was desirable. What was envisaged was a low cost computer data acquisition and storage system that would require little maintenance and would allow data transfer to a microcomputer for analysis.

2. Materials

(a) Temperature Logger

A Model XL-800 Data Logger developed and manufactured by Richard Brancker Research Ltd. in Ottawa, Canada was purchased for this project. The unit is an 8 channel, 12 bit resolution data logger capable of operating up to 6 months on a single set of four AA batteries. It was purchased with a set of eight 0.1°C resolution temperature sensors (thermistor type) with 10 meter leads. The XL-800 has a total storage capability of 57,000 readings and is IBM PC compatible through an RS232 interface. Additional information on the XL-800 is provided in Appendix B.

(b) Cement

Type 10 cement was supplied by Canada Cement Lafarge Ltd. and was delivered in paper bags. All cement was free of lumps and was free flowing. The chemical analysis of the cement, produced at their Brookfield, Nova Scotia plant, is included in Table I.

(c) Air Entraining Agent

The air entraining agent was a sulphonated hydrocarbon type AEA supplied by W.R. Grace.

(d) Aggregates

The fine and coarse aggregates were obtained from the Blagdon Pit. Results of tests carried out on the aggregate are given in Table I.

3. PLACEMENT OF THE TEMPERATURE SENSORS

Concrete prisms incorporating temperature sensors were cast with nominal dimensions 305 x 305 x 915 mm and 150 x 150 x 520 mm, respectively. In the large prism sensors were located in the horizontal plane at mid prism level with concrete cover of 25, 75, and 150 mm. The mold was modified to allow the 3 sensor wires to enter the prism through a flange attached to 5/16 inch stainless bolts imbeded in the concrete. In the small prism the

temperature sensor was located at the center of the specimen. The sensor wire exited the prism through the end. During casting the sensors were held in positon in the prisms with monofilament nylon. A photograph of setup used is included in appendix B.

4. Batching and Mixing

To facilitate handling of the various ingredients and to enable adjustments to be made to the mix, the ingredients were batched in two lots of equal size. The fine and coarse aggregates, and cement were weighed out in plastic buckets.

The mixer was started and one half the fine aggregates, one half the coarse aggregates, one half the cements, in that order, were dumped by hand into the mixer. Immediately prior to charging the mixer one half of the air- entraining admixture was added to one litre of water and stirred. Once half the cement was in the mixer, one half the water was added followed by the addition of the air entraining admixture.

Air content by the pressure method and slump were determined after 5 minutes of continuous mixing. Any changes that needed to be made were incorporated into the second half of the mix. The balance of the constituents of the mix were added in the same manner as the first half and mixed for an additional 5 minutes. Details of the mix are given in Table II. When mixing was completed, the concrete was discharged into a wheelbarrow and remixed with a shovel.

Specimens were cast in two layers of equal thickness and consolidated by vibration after each addition of concrete. Hand

scoops were used in placing the concrete and care was taken not to disturb the monofilament holding the temperature sensors

5. Testing of the Plastic Concrete

Prior to casting, the concrete was tested for air content by the pressure method. Slump and unit weight were also determined. The concrete was consolidated using a vibrating table. The temperature of the concrete was measured using a steel jacketed thermometer. The properties of the plastic concrete can be found in Table II.

6. Installation of Temperature Recorder at Treat Island

Two days after casting the prisms were demoulded and transfered to the moist cure room. After 56 days of moist curing the specimens were removed and allowed to air dry for one week. Equipment tests were performed before transport . On October 23, 1987 the two prisms were shipped to Eastport, Maine. They were taken by boat and unloaded on the site at mid tide level. The specimens were secured to the deck with stainless steel straps. The sensor wires were placed in a 50 mm diameter polyethylene conduit for protection. The XL-800 data logger was mounted on the inside wall of the equipment shed. The logger was connected to an IBM PC portable computer for programming and verification of operation.

7. Performance Tests on the XL-800 Logger

In addition to lab testing of the XL-800, two test runs were made on the unit after it was installed at the site. The first was conducted on October 23-24 ,1987. During the test temperatures sensors were read at 10 minute intervals for a 24 hour period. Test results fot the large prism are given in graphical and tabular form in appendix C. The sensors with 75 and 150 mm cover give fairly close readings. The sensor with 25 mm cover registered the greatest temperature extremes.

For the period of October 24 to November 23, 1987 tmeperature readings were made at 15 minute intervals. The corresponding graphs are given in appendix C. Over this time period the large prism experienced 8, 6, and 6 freeze-thaw cycles for the temperature sensors with 25, 75, and 150 mm cover, respectively. The temperature sensor in the small prism with 75 mm of cover experienced a total of 10 freeze-thaw cycles. Clearly the effect of concrete cover and specimen size are illustrated by these results.

APPENDIX A

APPENDIX "A"

STATEMENT OF WORK

A. Yearly Inspection of Fly Ash/Slag/Silica Fume Concrete Test Specimens at Treat Island

The contractor shall travel to Treat Island and clean, test and inspect 159 fly ash/slag/silica fume concrete prisms (305x305x910 mm) that have been installed at Treat Island during the period 1978-1987.

The contractor shall carry out the following:

a) clean and label each concrete prism
b) visual inspection and rating of each concrete prism
c) provide one colour print of each specimen
d) provide one colour slide of each specimen
e) retag specimens where necessary
f) obtain available temperature records to determine the number of cycles of freezing and thawing for the 1986-1987 winter
g) provide 5 copies of the report on testing and inspection; the report shall also include a photographic record of the test specimens.

B. Installation of Temperature Sensors at Treat Island

The contractor shall obtain two TL-100 Submersible Temperature Loggers from the manufacturer, Richard Bracker Research Ltd. One of them shall be installed in air at mid-tide level and one shall be cast into a 305x305x910 mm concrete prism and placed similarly. Prior to installation in air or casting in concrete the performance and suitability of the temperature loggers will be verified by preprogramming with an IBM PC portable computer and testing. Performance test will include temperature cycling in air (-20 to +40°C) and water (-0 to 30°C). After 90 days of moist curing of the concrete prism (w/c = 0.4, 5-7% air, Blagdon FA and CA) the prism containing the temperature logger and the logger for monitoring air temperature will be transported to Eastport, Maine and installed at the Treat Island Exposure site on or before November 1, 1987. The temperature logger for monitoring air temperature shall be secured to the deck using a steel frame and lag bolts. The concrete temperature recorder will be placed in a compartment in the concrete prism so that it can be retrieved for servicing and returned to the prism.

The contractor shall provide 5 copies of the report describing the testing and installation of the above system.

C. Preparation of Display Panels for 1988 Inspection at Treat Island

The contractor shall prepare a series of COREX plastic panels (approximately 6 mm thick) to describe the progress of on-going test programs at Treat Island, stating the following:

1. Phase No.
2. Title
3. Purpose
4. Results
5. Conclusion

.../

Individual Panels shall be prepared for Phases I(a) and I(b) and Phase 2 to Phase 7 inclusive plus an additional two plastic panels that give details of the 1987 work. This gives a total of 10 panels that will have a width and length sufficient to hold the required text.

The lettering shall be by vinyl, stencil or computer graphics lettering. If computer graphics lettering is used it shall be on plastic based paper or plastic coated paper with waterproof ink that can be subsequently glued to the COREX panels. Also if computer graphics lettering is used the text shall be readily updated for subsequent biennial inspections.

Panels shall be prepared in 1987 and stored until August 1988 at which time it will be transported to the Treat Island exposure site and displayed at the time of biennial inspection.

Deadlines

Part A - Completion of Report: October 31, 1987
Part B - Completion of Report: November 30, 1987
part C - Completion of Displays: January 31, 1988

AMMENDMENTS TO THE ORIGINAL CONTRACT

The two TL-100 Submersible Temperature Loggers specified in the original contract were, after consultation between T.W. Bremner and CANMET, supplemented with a single Model XL-800 Data Logger from the same manufacturer. The XL-800 was a newer more advanced unit that was not in production at the time of the contract proposal. This unit offered faster temperature response time, improved ease of use and greater sensing capabilities with a total of 8 temperature sensors.

It was agreed that T.W. Bremner would absorb the price differential between the XL-800 and two TL-100 units. See attached letter.

UNIVERSITY OF
NEW BRUNSWICK Post Office Box 4400 \ Fredericton, N.B. \ Canada E3B 5A3

Department of Civil Engineering
(506) 453-4521

Telex: 014-46-202

1987 06 18

Mr. George Carette
CANMET
Energy, Mines and Resources, Canada
405 Rochester Street
Ottawa
Ontario K1A 0G1

Dear George:

Richard Brancker Research Ltd., manufacturers of the TL-100 submersible temperature logger will have a new 8 channel logger, the XL-800, available in mid August 1987. Jeff and I feel that this unit would better suit CANMET's present and future needs.

The XL-800 will be housed in the equipment shed at Treat Island. It will be connected by flexible conduit to one temperature sensor in the air and one in the center of a 305 x 305 x 915 mm concrete prism on the deck. The temperature sensors will be of either thermistor or thermocouple design. With the data logger located in the equipment shed, the retrieval of data and the system maintenance will be made easier. Also, the possibility of physical damage to the data logger will be greatly reduced.

We will absorb the price differential incurred by going with the XL-800 system, so that the contract price will remain the same. Please let us know if the above is not satisfactory.

Sincerely,

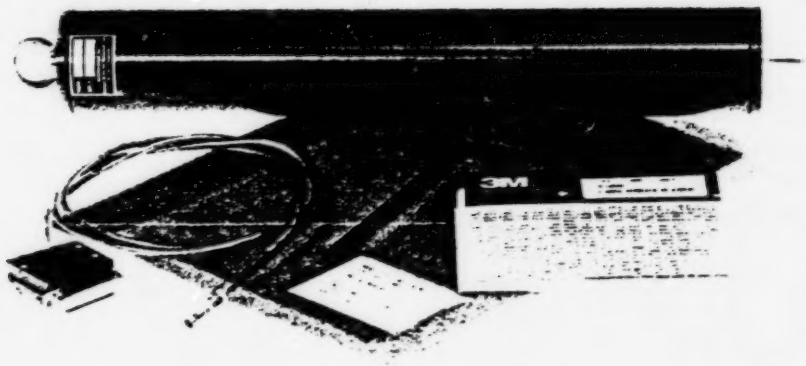
Theodore W. Bremner, P.Eng., Ph.D.
Professor of Civil Engineering

TWB*gs

APPENDIX B

SUBMERSIBLE
SINGLE CHANNEL LOGGERS

MODEL XL-100



The Model XL-100 is a single channel logger supplied with an integral temperature probe. The time constant for the standard probe is ten seconds.

The standard cases of the loggers are of black anodized aluminum and are designed to withstand pressures of up to 1000 metres of water. Versions with stainless steel or PVC cases may be supplied to special order.

Temperature measurements are made using a linear pair of thermistors and a 12-bit plus sign analogue to digital converter to give 0.1°C resolution over the range -20 to +50°C. The XL-100 contains a real time clock and may be programmed to take measurements at any sample rate from 1 second to 1 day. The data may be collected either for a fixed interval or in a continuous mode.

The XL-100 are programmed, and data retrieved, via a serial link to an IBM-PC type computer. Software for accessing the loggers, display of the data and production of spreadsheet-compatible data files are included.

■ SPECIFICATIONS

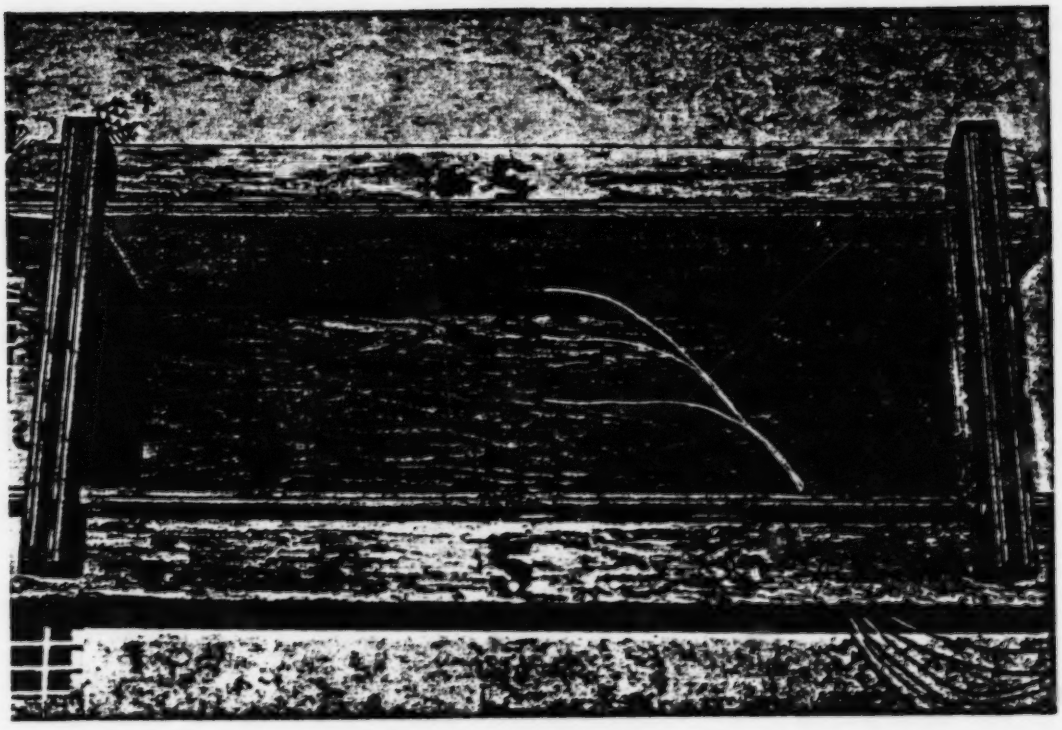
SIZE: 6cm diameter, 38cm long (excluding sensor)
WEIGHT: 2 kg
MAIN POWER: Qty 4 Alkaline 'AA' cells
MEMORY BACKUP: 1 Lithium cell
OPERATING TEMPERATURE: -40 to +85°C
RUNNING TIME: 6 months
AVAILABLE MEMORY: 16000 samples
SAMPLE RATE: Programmable 1 second to 1 day
START TIME: Programmable Year: Month: Day: Hour: Minute: Second
END TIME: Programmable Year: Month: Day: Hour: Minute: Second
SAMPLE RESOLUTION: ±0.1°C
SAMPLE ACCURACY: ±0.2°C
UNIT INTERFACE: RS232 serial line, 9600 baud
INTERROGATION DEVICE: IBM PC or equivalent with one serial port

25 October 1987

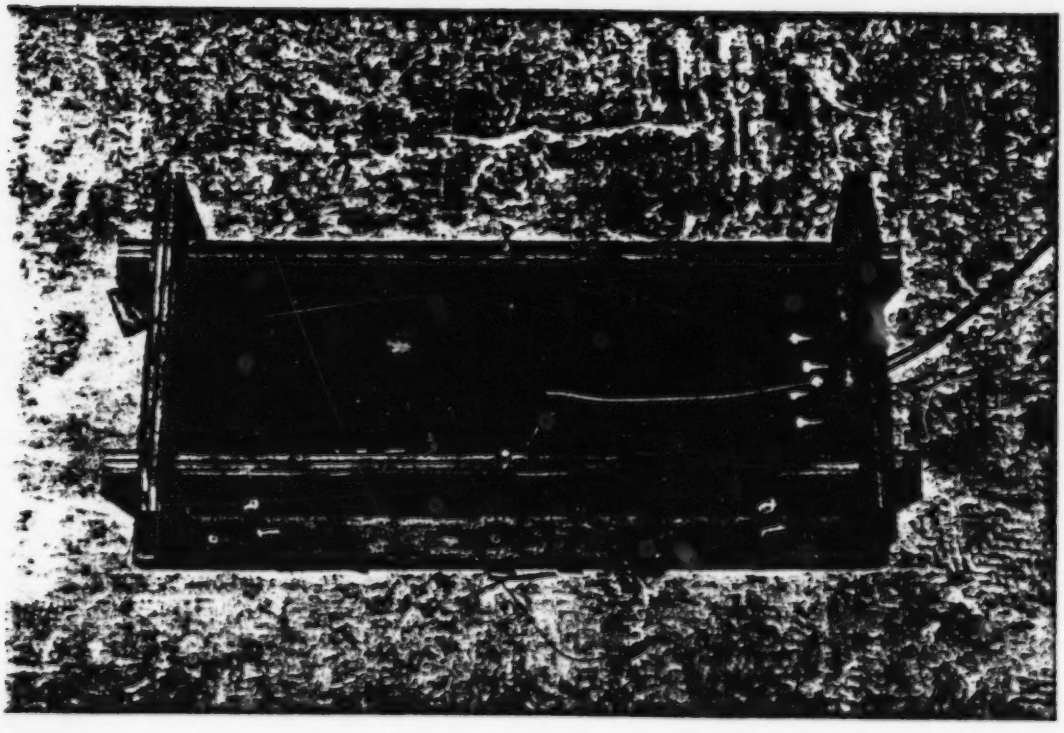
The XL-100 is a new product; PRICE: $1,000.00
c/w Software Package fob Ottawa.

Other Models i.e. 2 channel, 8 channel also available.
Please phone (613)233-1621 or write for data.

RICHARD BRANCKER RESEARCH LTD. (613) 233-1621
27 Monk Street, Ottawa, Canada K1S 3Y7 Telex 053-4761

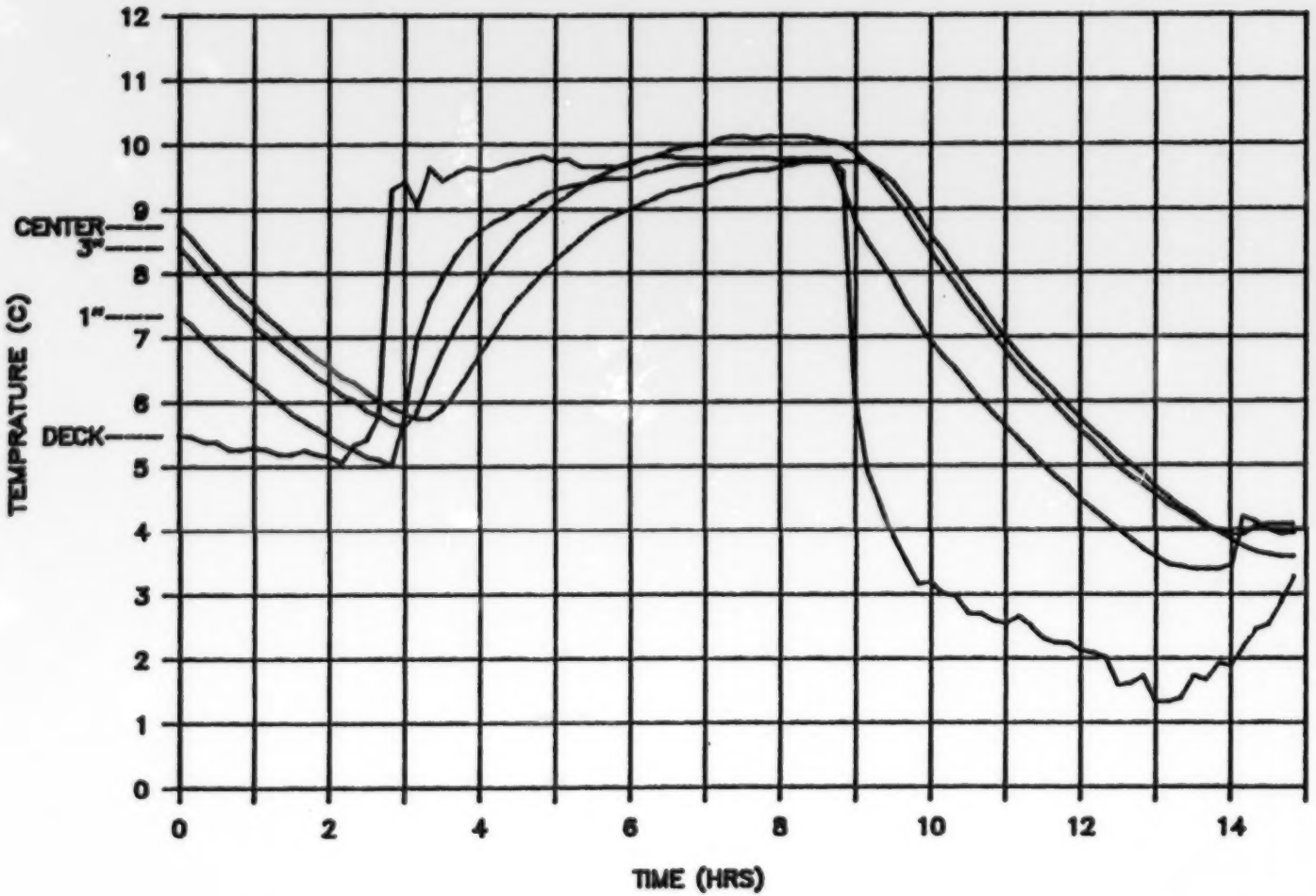


Photograph of large prism showing location of temperature sensors



Photograph of small prism showing location of temperature sensor

APPENDIX C

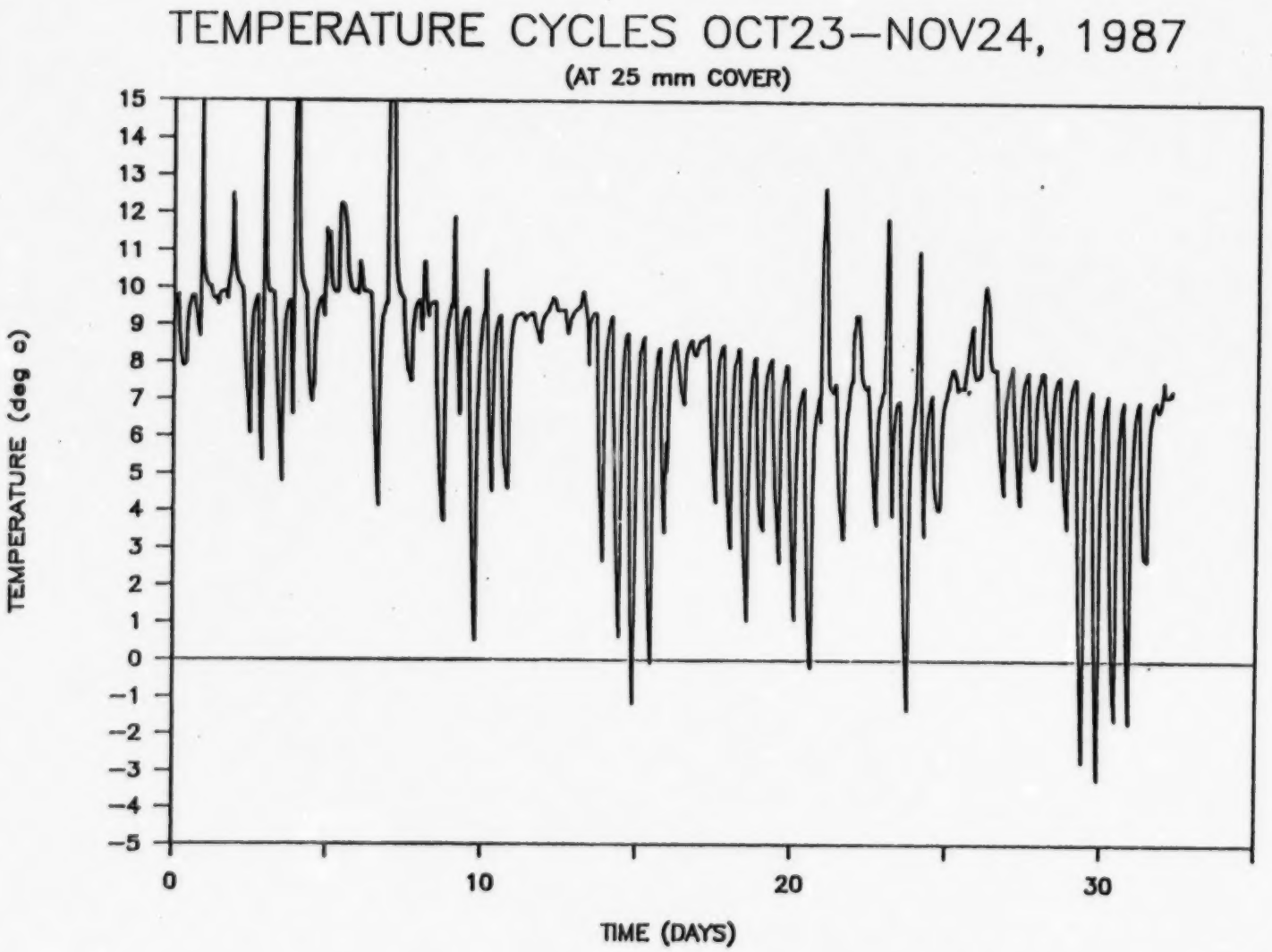

TEMP PROFILE AT TREAT ISLAND OCT 23–24
TEMPRATURE (C)
TIME (HRS)
CENTER
3"
1"
DECK
0
1
2
3
4
5
6
7
8
9
10
11
12
0
2
4
6
8
10
12
14

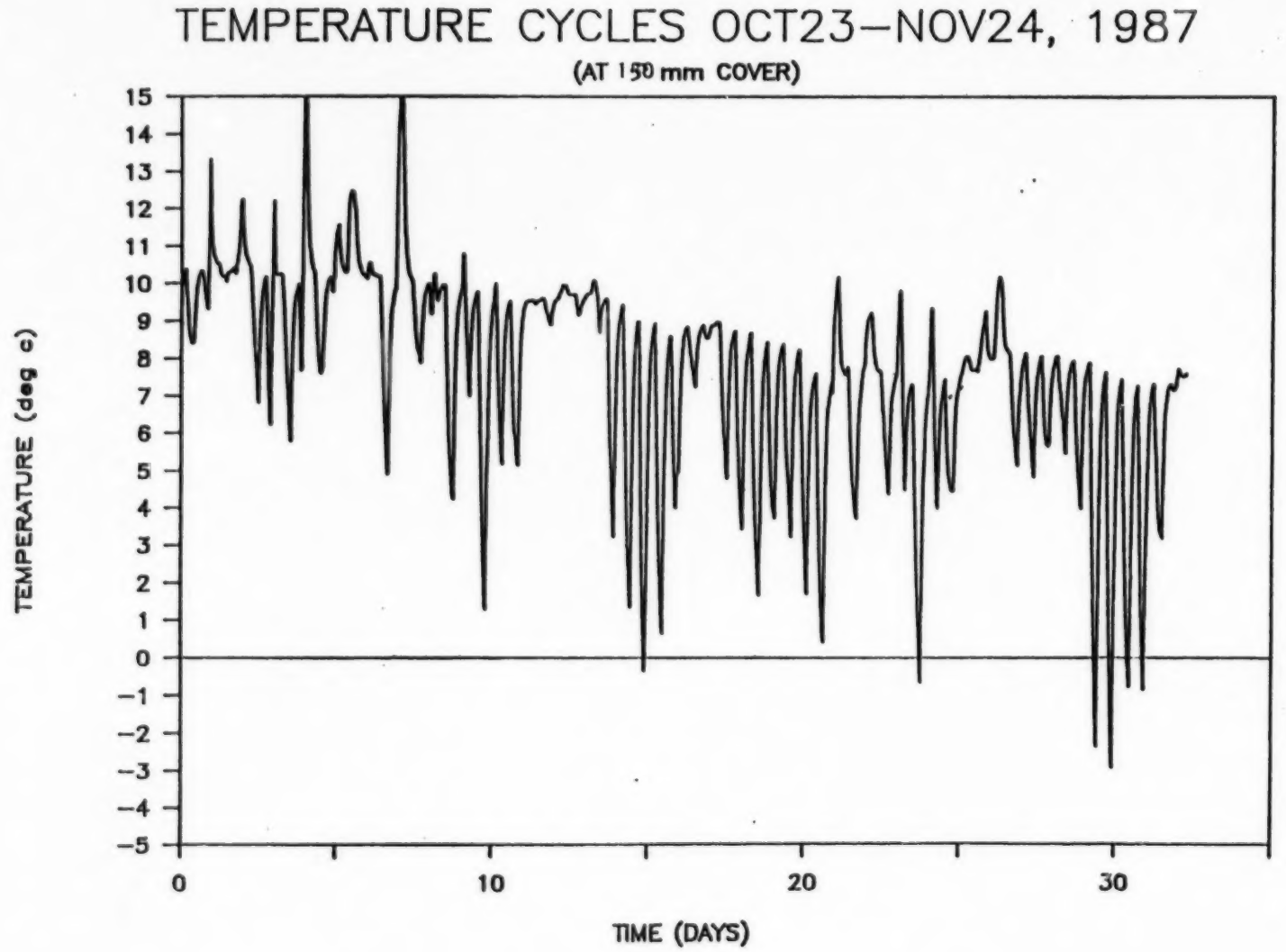
TEMPERATURE PROFILES FOR OCTOBER 23-24, 1987 (AT TREAT
(IN DEGREES C)

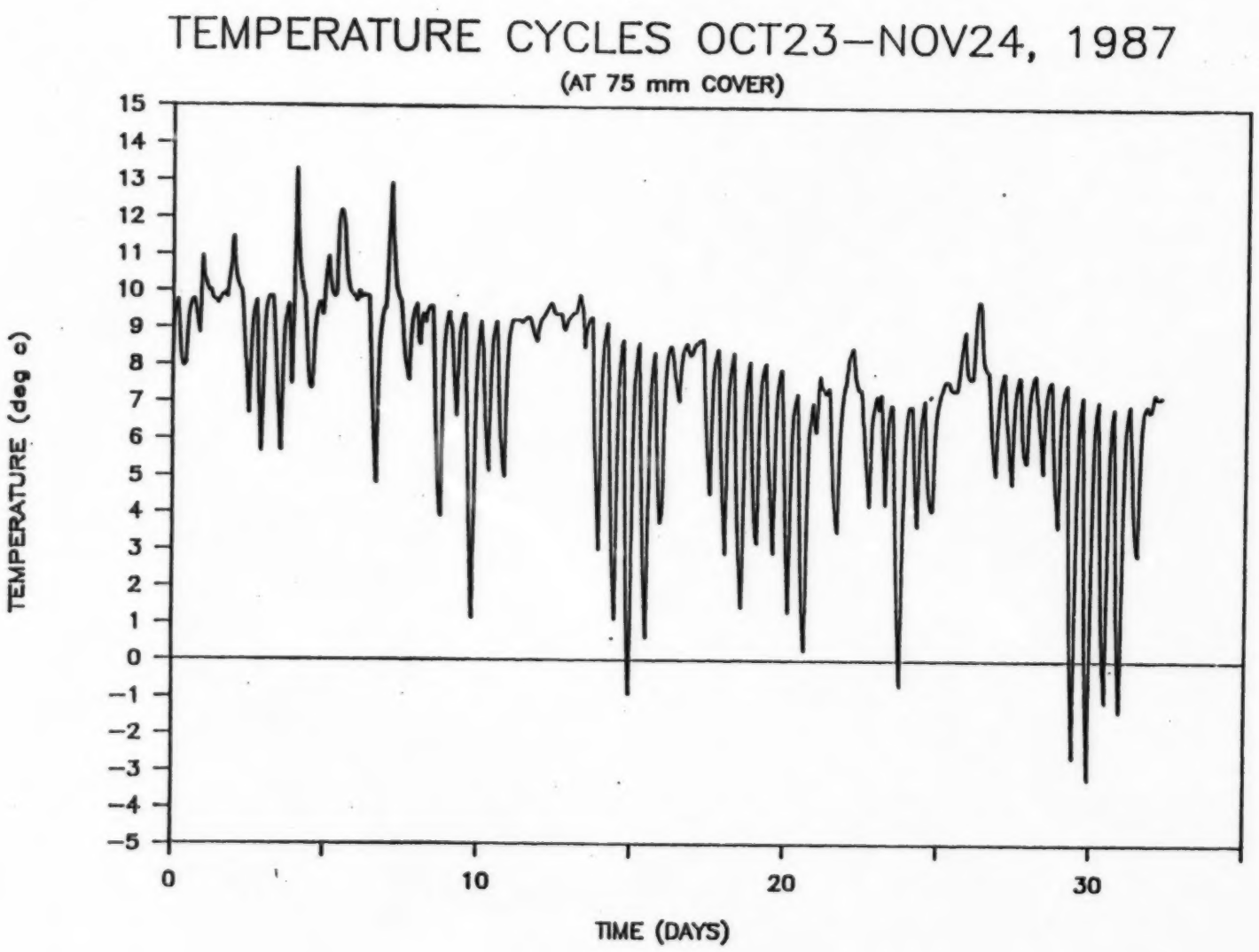
TIME	1'x 1' x 3' PRISM CONCRETE COVER			DECK
	1"	3"	6"	
07:00 PM	7.4	8.4	8.8	5.5
07:10 PM	7.2	8.2	8.6	5.5
07:20 PM	7.0	8.0	8.3	5.4
07:30 PM	6.8	7.8	8.1	5.4
07:40 PM	6.6	7.6	7.9	5.3
07:50 PM	6.5	7.4	7.7	5.3
08:00 PM	6.3	7.2	7.5	5.3
08:10 PM	6.1	7.0	7.3	5.3
08:20 PM	6.0	6.9	7.2	5.2
08:30 PM	5.8	6.7	7.0	5.2
08:40 PM	5.7	6.5	6.8	5.3
08:50 PM	5.6	6.4	6.7	5.2
09:00 PM	5.5	6.3	6.5	5.1
09:10 PM	5.3	6.1	6.4	5.1
09:20 PM	5.3	6.0	6.3	5.3
09:30 PM	5.1	5.9	6.1	5.4
09:40 PM	5.1	5.8	6.0	5.8
09:50 PM	5.0	5.7	5.9	9.3
10:00 PM	5.8	5.6	5.8	9.4
10:10 PM	7.0	5.9	5.7	9.1
10:20 PM	7.6	6.3	5.7	9.7
10:30 PM	7.9	6.8	5.9	9.4
10:40 PM	8.3	7.2	6.1	9.6
10:50 PM	8.5	7.5	6.4	9.7
11:00 PM	8.7	7.8	6.7	9.6
11:10 PM	8.8	8.1	7.0	9.6
11:20 PM	8.9	8.3	7.4	9.7
11:30 PM	9.0	8.6	7.6	9.7
11:40 PM	9.1	8.8	7.8	9.8
11:50 PM	9.2	8.9	8.0	9.8
12:00 AM	9.3	9.1	8.2	9.7
12:10 AM	9.4	9.2	8.4	9.8
12:20 AM	9.4	9.4	8.6	9.7
12:30 AM	9.4	9.5	8.7	9.7
12:40 AM	9.5	9.6	8.8	9.7
12:50 AM	9.5	9.7	8.9	9.7
01:00 AM	9.5	9.7	9.0	9.7
01:10 AM	9.6	9.8	9.1	9.8
01:20 AM	9.6	9.8	9.2	9.8
01:30 AM	9.7	9.9	9.3	9.8
01:40 AM	9.7	10.0	9.3	9.8
01:50 AM	9.7	10.0	9.4	9.8
02:00 AM	9.7	10.0	9.4	9.8
02:10 AM	9.7	10.1	9.5	9.8
02:20 AM	9.8	10.1	9.5	9.8
02:30 AM	9.8	10.1	9.6	9.8
02:40 AM	9.8	10.1	9.6	9.8

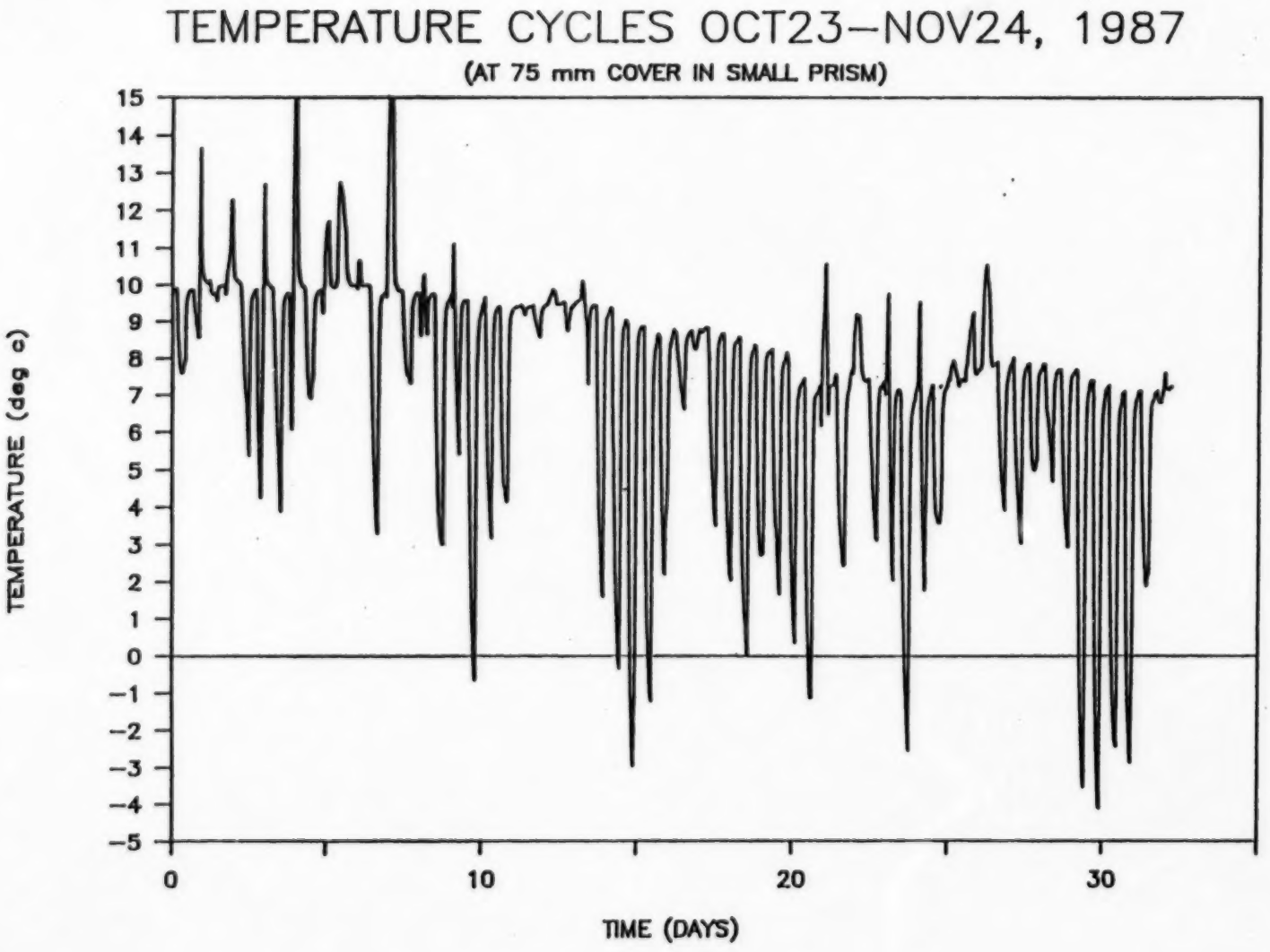
TEMPERATURE PROFILES FOR OCTOBER 23-24, 1987 (AT TREAT
(IN DEGREES C)

TIME	1'x 1' x 3' PRISM CONCRETE COVER			DECK
	1"	3"	6"	
02:50 AM	9.8	10.1	9.6	9.8
03:00 AM	9.8	10.1	9.7	9.7
03:10 AM	9.8	10.1	9.7	9.7
03:20 AM	9.8	10.1	9.7	9.7
03:30 AM	9.8	10.1	9.7	9.7
03:40 AM	9.8	10.0	9.7	9.7
03:50 AM	9.3	10.0	9.7	9.6
04:00 AM	8.8	9.9	9.7	6.1
04:10 AM	8.5	9.7	9.7	4.9
04:20 AM	8.2	9.4	9.6	4.4
04:30 AM	7.9	9.2	9.4	3.9
04:40 AM	7.5	8.9	9.1	3.5
04:50 AM	7.2	8.6	8.9	3.2
05:00 AM	6.9	8.3	8.6	3.2
05:10 AM	6.7	8.1	8.3	3.0
05:20 AM	6.5	7.8	8.1	3.0
05:30 AM	6.3	7.5	7.8	2.7
05:40 AM	6.0	7.3	7.5	2.7
05:50 AM	5.8	7.0	7.2	2.6
06:00 AM	5.6	6.8	7.0	2.5
06:10 AM	5.4	6.5	6.7	2.7
06:20 AM	5.2	6.3	6.5	2.5
06:30 AM	5.0	6.1	6.3	2.3
06:40 AM	4.8	5.9	6.1	2.2
06:50 AM	4.7	5.7	5.9	2.2
07:00 AM	4.5	5.5	5.7	2.1
07:10 AM	4.3	5.4	5.5	2.1
07:20 AM	4.2	5.2	5.4	2.0
07:30 AM	4.0	5.0	5.2	1.6
07:40 AM	3.8	4.8	5.0	1.6
07:50 AM	3.7	4.7	4.9	1.7
08:00 AM	3.6	4.6	4.7	1.3
08:10 AM	3.5	4.4	4.5	1.3
08:20 AM	3.4	4.3	4.4	1.4
08:30 AM	3.4	4.2	4.2	1.7
08:40 AM	3.4	4.0	4.1	1.7
08:50 AM	3.4	4.0	4.0	1.9
09:00 AM	3.5	3.9	3.8	1.9
09:10 AM	4.2	3.9	3.7	2.2
09:20 AM	4.1	4.0	3.7	2.5
09:30 AM	4.0	4.1	3.6	2.5
09:40 AM	3.9	4.1	3.6	2.9
09:50 AM	4.0	4.1	3.6	3.3


TEMPERATURE CYCLES OCT23–NOV24, 1987
(AT 25 mm COVER)
TEMPERATURE (deg c)
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
−1
−2
−3
−4
−5
0
10
20
30
TIME (DAYS)


TEMPERATURE CYCLES OCT23–NOV24, 1987
(AT 150 mm COVER)
TEMPERATURE (deg c)
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
−1
−2
−3
−4
−5
0
10
20
30
TIME (DAYS)


TEMPERATURE CYCLES OCT23–NOV24, 1987
(AT 75 mm COVER)
TEMPERATURE (deg c)
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
−1
−2
−3
−4
−5
0
10
20
30
TIME (DAYS)


TEMPERATURE CYCLES OCT23–NOV24, 1987
(AT 75 mm COVER IN SMALL PRISM)
TEMPERATURE (deg c)
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
−1
−2
−3
−4
−5
0
10
20
30
TIME (DAYS)

TABLES

TABLE I

Test Results on Material Used

Physical properties and chemical analyses of cement	
Description of tests	Portland Cement CSA Type 10
Physical tests - fineness	
Fineness- passing 75 µm, %	-
- passing 45 µm, %	84.5
- blaine, m^2/kg	390
Normal consistency, %	-
Setting time, min	106
Autoclave expansion, %	0.04
Physical tests - mortar strength	
Water content, %	-
Flow %	-
Compressive strength, MPa	
3-day	28.1
7-day	32.9
28-day	38.3
Pozzolanic activity with portland cement, %	-
Water requirement, % of control	-
Pozzolanic activity with lime, MPa	-
Chemical analyses	
SiO_2, %	20.42
CaO, %	62.65
CaO (free), %	0.66
Insoluble, %	0.91
LOI, %	2.25
Al_2O_3, %	5.95
Fe_2O_3, %	2.21
SO_3, %	3.79
MgO, %	1.46
Na_2O, %	-
K_2O, %	-
Alkalies (as Na_2O),	0.98
$CaSO_4$, %	-
C_3A, %	-

TABLE I (Cont'd)

Sieve Analysis of Fine Aggregate

Sieve Size	% Passing	CSA % Passing
5 mm	99.9	95 - 100
2.5 mm	86.7	80 - 100
1.25 mm	68.0	50 - 90
630 µm	46.2	25 - 65
315 µm	21.6	10 - 35
160 µm	8.0	2 - 10
PAN	1.6	0

Sieve Analysis of Coarse Aggregate

Sieve Size	% Passing #4 - 3/4	CSA % Passing
20 mm	100	90 - 100
14 mm	85.9	-
10 mm	54.4	25 - 60
5 mm	4.3	0 - 10
2.5 mm	2.1	0 - 5
1.25mm	2.0	-
PAN	0	-

TABLE II

Concrete Mix Data

MIX NUMBER: TEMPERATURE SENSOR PRISMS
DATE: 87-08-18

AGGREGATE MOISTURE LEVELS (%)

fine aggregate:	0.71
coarse aggregate:	1.05

MIX PROPORTIONS in (kg/m)

cement:	431 kg/m^3
fine aggregate:	702 "
coarse aggregate:	1002 "
water (total):	172 "
AEA	250 ml/m^3

PROPERTIES OF FRESH CONCRETE

temperature:	25
slump (mm):	62
air (%):	6.0
w/c:	0.4
unit weight:	2340